BARKER

Design for a Purification Plant for the Water Supply Of the University of Illinois

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DESIGN FOR A PURIFICATION PLANT FOR THE WATER SUPPLY OF THE UNIVERSITY OF ILLINOIS

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

LAWRENCE BYRON BARKER

ENTITLED DESIGN FOR A PURIFICATION PLANT FOR THE WATER SUPPLY OF THE UNIVERSITY OF ILLINOIS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Municipal and Sanitary Engineering

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A DESIGN FOR A PURIFICATION PLANT FOR THE WATER SUPPLY OF THE UNIVERSITY OF ILLINOIS.

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It is the purpose of this thesis to design a plant for the purification of the water supply of the University of Illinois. This supply now amounts to about 130 000 gallons per day, drawn from four wells 160 feet deep. The following analysis and descriptions of the water is taken from a paper on "Laboratory Experiments in Water Treatment" by Edw. Bartow and J. M. Lindgren.

Potassium Nitrate,	1.1	parts per million.
Potassium Chloride,	2.9	do.
Sodium Chloride,	3.5	do.
Sodium Sulphate,	3.6	do.
Sodium Carbonate,	60.5	do.
Ammonium Carbonate,	6.1	do.
Magnesium Carbonate,	121.2	do.
Calcium Carbonate,	175.2	do.
Iron Carbonate,	2.1	do.
Aluminum,	2.5	do.
Silica,	18.9	do.

"On exposure to air the water becomes turbid. A considerable quantity of sediment collects in the mains. This sediment varies in color from black to red, according to the degree of oxidation of the iron salts. There is frequently

trouble from crenothrix, and beggiatoa, which is responsible for an unpleasant odor has been isolated. In boilers there is a formation of sludge or a soft scale which may clog the steam pipes. Corrosion of the joints and valves is frequent."

There is practically no danger from outside pollution. The chief difficulty is the iron which promotes the growth of crenothrix, and when oxidized forms an objectionable precipitate. The problem of purification, then, is essentially the removal of this iron, and, incidentally, a softening of the water. As a result of the experiments mentioned above it was concluded that such a purification could be successfully accomplished by treatment with lime accompanied by sedimentation and final filtration. Experimental work along this line is now being carried on, but the results are not as yet available.

I. GENERAL DESIGN.

The design of such a system is governed by existing conditions. It is desirous to utilize as much as possible of the old apparatus, to keep the plant compact and near the present pumping station, and to keep the expense of construction within reasonable limits.

In choosing the design of the general arrangement of parts two plans were considered. They were alike in that they both involved the sedimentation and coagulant basin and two or more rapid sand filters. By the first plan the water would be pumped directly into the sedimentation basin from the wells. Passing through this and the filters it would flow into a small wet well, and be pumped from there to the two tanks now used for storage tanks. This scheme is small in first cost as it saves the expense of a large clear water well and could probably be built several feet lower, and so lighten the walls. On the other hand it makes a very inelastic system as there is no chance for storage except for the two tanks and no way of regulating the flow into the sedimentation basin. It would be necessary to install a new pump of a capacity equal to the average rate of consumption, and there would be considerable expense of pumping.

The second plan involves the use of the two storage tanks to regulate the flow into the sedimentation basin and to keep it constant in case the rate of pumping fluctuates or the pumps are stopped. The water would be pumped into these tanks from the wells, as at present, and would flow from them by gravity onto the sedimentation basin. From the filters it would pass to a large clear water well capable of holding several hours supply and would be pumped from there into the pressure tanks. This plan involves a larger initial expense in building the clear water well, and because of the greater height the walls would have to rise above the ground level and they would be much heavier, but the cost of operation and maintenance would be small. It would make a very elastic system--one in which the flow would be very regular independent of the rate of pumping, and which could furnish almost a day's supply without flow from the wells.

After a consideration of the advantages and disadvantages as set forth above, the second scheme was chosen as the most economical design for the requirements of this particular problem.

As stated before, the water consumption of the University is now only 130 000 gallons per day. This, however, is scarcely sufficient for the present demand, so in designing for a period of ten or more years ahead a maximum capacity of 250 000 gallons per day is allowed for.

The most available and convenient site for the plant is the space just south of the "Bone-Yard", the small stream flowing through that part of the campus, and between the Ceramics Laboratory and the roadway west of it. This site is adjacent to the pumping station and easily accessible from it. The use of it for this purpose will not interfere with the erection of new buildings or the extension of old ones, and the Bone-Yard affords easy drainage to all parts of the plant.

II. SEDIMENTATION.

It is rapidly becoming a recognized fact that one of the most important factors of successful filtration is sufficient time for sedimentation. Most of the earlier plants provided very short periods for sedimentation, some no more than an hour and the majority under two hours. In such a short time there can be but little settling of the suspended matter, even if the reaction of the chemical with the raw water were completed. As it is, a great deal of the precipitate is carried over into the filters, causing them to become clogged, a part of the reaction taking place in the filter itself so that a crystalline deposit forms on the filtering material, enlarging the individual grains and cementing them together until the effective size is several times what it was at first, and the alkalinity of the filtered water is sometimes even higher that that of the raw on account of the quantities of unchanged chemical which is carried through the filters.

Experiments on the University water have shown that although the reaction of the lime with the raw water is practically completed in six hours, it goes on to some extent for twelve or even eighteen hours longer. In designing the sedimentation basin in question, to allow for as complete a reaction and sedimentation as is possible without the cost becoming exorbitant, a period of eight hours was decided upon.

Considering the maximum capacity--250 000 gallons per day--this means a nominal capacity of 83 500 gallons, or 11 150 cubic feet. Twelve feet was found to be the most economical depth of flow. This leaves an available head on the two supply tanks of about nine feet, and permits ground dimensions of 25 x 40 feet.

The basin is designed without any baffles to direct the flow as it is the experience of most operators of filter plants that such baffles are a detriment rather than an aid to proper sedimentation. The chemical tanks, which will be described in a separate article, are situated in the filter house at the north end of the reservoir.

A common fault of chemical precipitation is that there is insufficient mixing of the chemical and the raw water. The arrangement for providing an opportunity for a thorough mixing is probably the only feature of the sedimentation basin that is in any way unique. The 6-in. supply pipe from the tanks in the pumping station is brought in under the wall at the north-west corner. Just inside the wall it rises vertically through the floor to a height about fifteen inches above the water level, as shown on Plate II. It then discharges through an automatically controlled butterfly valve into a concrete channel eighteen inches square and open at the top. This channel extends along the west wall the entire length of the reservoir. It has a drop of six inches between ends, and is provided with

baffle plates arranged alternately from each side at intervals of eight feet, leaving a clear space of six inches at each baffle. It is thought that in passing through this channel the chemical and the raw water will become thoroughly mixed and a favorable condition for a complete reaction brought about before the water is finally emptied into the reservoir itself.

At the south end of this channel a vertical 8-in. pipe enters it through, and coming just flush with, the bottom. At a depth of six feet this vertical pipe turns horizontal and runs parallel to the south wall. At intervals of five feet along this horizontal pipe there are four 8 x 4-in. tees through which the flow is distributed.

The effluent system of the sedimentation basin is very simple. The 8-in. supply pipe to the filters is through the middle of the north wall at an elevation of 8 feet above the floor. Just inside the wall it is connected by a tee with an 8-in. horizontal pipe parallel to the wall. From this pipe and opposite the 4-in. influent pipes at the south end, rise four 6-in. pipes. These are open at the top, and, rising to about four inches below the level of the water, serve as circular submerged weirs.

The floor of the reservoir is made to slope to the middle of the north end where there is a shallow sump. An 8-in. cast-iron pipe, controlled by a slide valve, drains from this directly into the creek. Back of the valve this is

connected to an overflow pipe, also 8 in. in diameter, which rises to six inches below the top of the reservoir wall. Besides serving to drain the basin the pipe to the creek is to be used to carry off the accumulated sediment, which will be washed down by a stream of filtered water from the mains.

III. FILTERS.

In designing the filters, a nominal rate of 125 000 000 gallons per acre per day was used. Such a rate requires a filter area of about 100 square feet for the maximum flow. As the present rate is only about one-half this maximum, it was decided to divide the total area into smaller units and to fit up only as many of these units as are needed at the present time. If filtration is to be constant, two is the minimum number of units which can be used. At the present rate of consumption, two filters, seven and one-half feet long by four feet wide will easily take care of the supply, and space will be left for the construction of two more as the demand increases.

As designed, the filters have a head of four feet of water above the sand. The sand layer is thirty-six inches deep and is underlaid by six inches of graded gravel over the under-drains. There is no mechanical stirring device but the washing is to be done by filtered water from the pressure mains, and the sand is to be agitated by compressed air.

The piping system of the filters is shown on Plates IV & V. For the sake of clearness in describing the piping, the west filter will be referred to as No. 1 and the other as No. 2. As the piping on the two sides of the gallery are almost the same only that on the west side will be described, except where the arrangement of No. 2 differs from it.

The 8-in. main supply pipe from the sedimentation basin divides into two 6-in. branches which pass to opposite sides of the pipe gallery. The 6-in. feed pipes to the filters are connected to these branches by three way specials, the third end of which is plugged but to which the connections for the additional filters may be made. The flow through the feed-pipe is controlled by a 6-in. slide valve and a butterfly valve, regulated by a float on the filter. To distribute the flow more uniformly over the surface of the filter a box-like contrivance is fitted into the end of the influent pipe. This is eighteen inches square and a foot deep, the bottom being just above the surface of the sand. The top is open and there are half-inch slots in the upper six inches but the bottom and lower half are closed. The water in flowing through this will fill it and flow through the slots and over the upper edge with a greatly decreased velocity.

The filtered water is drained off through the center of the filter bed instead of from one end, as is the usual practice. The writer believes that this plan will give a less loss of head and a correspondingly more uniform filtration than the older method. The main subdrain is a 4-in. pipe connected by a tee and a reducer with the 6-in. effluent pipe. Into this main sub-drain, at intervals of six inches, are tapped thirteen pairs of 2-in. laterals. Standard, semi-spherical brass strainers, one inch in diameter, are inserted into the upper side of the laterals at four inch intervals. The whole system of

sub-drains is embedded half its depth in the concrete floor of the filter.

There is no automatic regulation as it was believed that, considering the small size of the plant and the great loss of head caused by controllers, hand regulation would be more economical and fully as satisfactory. As a guide for hand regulation 6 x 2 1/2-in. venturi meters are placed in the effluent pipes between the filter connections and the main. The differences in head and the corresponding velocities of flow may then be read from gages on the floor above the pipe gallery.

As stated before, the washing is done by filtered water from the pressure mains. A 4-in. pressure pipe is located on each side of the main effluent pipe, and connections are made with the filter effluent pipes on the filter side of the controlling valve. A 4-in. compressed air main runs along the west side of the gallery. Branches from this, two inches in diameter, are tapped into the filter effluent pipe between the venturi meter and the sub-drain connection. It should be stated here that the air connection, as shown on Plate V, should be changed by lengthening the horizontal arm which connects with the filter effluent so that the connections to filter No. 2 will miss the valve of the wash water pipe. The reason for this change may be seen by reference to Plate V.

The channel for draining the wash water from the filters is half a 12-in. pipe, so placed that its upper edge is eighteen inches above the sand. It is unsupported save at the ends, which

are embedded six inches in the concrete end walls. As designed, this drain is at one side of the filter, close to the wall. It would probably be more efficient if it were located along the center line of the filter, but this would involve an awkward arrangement of the pipes in the gallery. The water is taken from the drain by a 6-in. waste pipe just inside the end wall. This pipe is controlled by a 6-in. slide valve. Just beyond this valve it turns downward and connects with the drain from the sedimentation basin. The connection with the waste pipe from filter No. 2 is made with the vertical pipe by a 6-in. x 6-in. x 6-in. tee.

A loss of head of eight feet in the filters and underdrains may be allowed before washing is necessary. A greater loss than this might be allowed if the water in the clear water basin is drawn down, but this is not advisable. It will probably not be necessary to clean the filters oftener than once a day.

All regulating valves, etc., may be operated from the floor above the filter gallery, which is built on a level with the top of the filter walls.

IV. CLEAR WATER WELL.

The necessity for a large reserve supply of filtered water is not as large a factor in this design as in the majority of purification plants. Here, where the water is not contaminated from any outside source, the use of raw water, even for several hours at a time, would have no harmful effect. It is well, however, that there should be a supply of filtered water sufficient to last for a few hours at the average rate of consumption in case it should be necessary, for any reason, to shut down the filters. In time of extraordinary demand, as for fire protection, unfiltered water could be drawn from the supply tanks or taken direct from the pumps. Under these conditions a clear-water well having a capacity of 30 000 gallons is sufficient.

The question of the location of the clear-water reservoir is governed in this case by the peculiarities of the site chosen for the plant. The only available place for a reservoir separate from the filters is on the opposite bank of the Bone-Yard. This would necessitate either a pumping pit into which the water could flow by gravity or a long suction pipe. Besides these disadvantages, the excavation for such a reservoir would probably come very close to the south wall of the Mechanical Engineering Laboratory, and might endanger it.

A plan has been adopted in the construction of some of the more recent plants, as at Albany, N. Y., of putting the clear-water well directly under the filters. This plan involves a complicated problem of walls and supports for the filters, but has the advantage of compactness and is economical. Here, the difficulty of excavating much below the creek bed prevents a very great depth being reached, but, allowing for a maximum loss of head of eight feet in the filters, a working depth of ten feet can easily be obtained. Then, to give the required capacity, with the length of the well equal to the width of the sedimentation basin, it is necessary to make the width eighteen feet. This width makes the well extend eight feet beyond the filters. This space is roofed over with concrete slabs from the north wall of the well to the filter wall at the level of the floor over the pipe gallery. This extra floor space is utilized for the chemical tanks and as a storeroom. The entrance to the filter building is at the west end of this space. A man-hole through the floor gives access to the well.

The floor of the clear-water well drains to the west side where a sump is located. A 10-in. suction pipe from the pressure pump connects with the bottom of this sump. No other drainage is provided.

V. COAGULANT.

In experimental work on the University water, the best results have been obtained by using eight grains of lime to the gallon of raw water. A saturated solution of lime water contains sixty-eight grains per gallon, so that with a consumption of two hundred and fifty thousand gallons per day almost thirty thousand gallons of lime water per day must be used. This excessively large amount makes the use of milk of lime advisable.

For mixing the milk of lime a shallow tank or mortar box, six feet long by three feet wide and a foot deep, is provided. This is set at an elevation of ten feet above the floor, and has a slight drop from one end to the other. Just under the end of this there is a storage tank, six feet in diameter and eight feet deep. This stands on a platform two feet high. In the bottom of the circular tank there is a system of brass grids connected with the compressed air mains. By sending a current of air through these at frequent intervals the solution may be kept from settling. The connection with the outlet into the raw water is by a one inch pipe along the west side of the filters. The flow may be regulated to correspond with the flow of the raw water by a pet-cock.

VI. CONSTRUCTION.

This plant is designed to be built entirely of concrete up to the level of the top of the wall of the sedimentation basin. In some parts reinforcement is used. This is designed as 0.8 percent of the net area of cross-section and consists of round mild steel rods.

The walls of the sedimentation basin are designed to withstand a head of twelve feet of water. Heavy buttresses at the corners and at eight foot intervals along the sides take up the overturning moment. These buttresses rise to two feet below the top of the wall, are two feet wide and have a length of eight feet at the base line. They are not reinforced except for horizontal rods extending back into the wall. The walls themselves are designed as beams with a length equal to the unsupported distance between buttresses. This is not theoretically correct, but the error is on the side of safety. They are twelve inches wide at the top and have a batter of one in twelve. They are reinforced by longitudinal rods closely spaced at the bottom and farther apart toward the top. On the north side the end walls and floor beams of the filters take the place of the buttresses.

The intermediate columns under the filters are designed to take only the weight directly above them, but the outside ones also take the horizontal stress transmitted to them by the end walls and beams of the filters. The north wall of the clear-water well is designed in the same way as those of the sedimentation basin, but in the east and west walls allowance is made for the outside pressure of the earth filling and the vertical weight of the water and sand in the filters.

The floors of the sedimentation basin and clear-water well are of concrete six inches thick and laid in place on a foundation of crushed stone. Those of the pipe gallery and filter house itself are of 4-in. concrete slabs. The filter floors are constructed of 6-in. reinforced concrete slabs, and over these cement mortar laid to the center line of the main sub-drain.

VII. PUMP CONNECTIONS.

The feed pipe to the sedimentation basin connects with what is now the 10-in. suction pipe from the tanks to the pump by a 10 x 10 x 6-in. tee. A 10-in. valve on the pump side of the connection cuts off the pump except in case of extraordinary demand. The 10-in. suction pipe from the clear-water well connects with the 12-in. suction main from the storage reservoir on the west side of the building. This pipe may also be cut off by a valve inside the pumping station.

VIII. CONCLUSION.

In making this design very little data regarding the effect of different periods of sedimentation, rates of filtration, amount of coagulant used, or advisable loss of head to be allowed for, were available. Such data would probably change various details of the design quite materially. As the question of cost has not been entered into the economical feature of the design can not be taken up here, but the writer believes that the present condition of the University water supply demands some method of purification, and the cost of such a plant as has been designed would be no greater than the benefits resulting from its use.

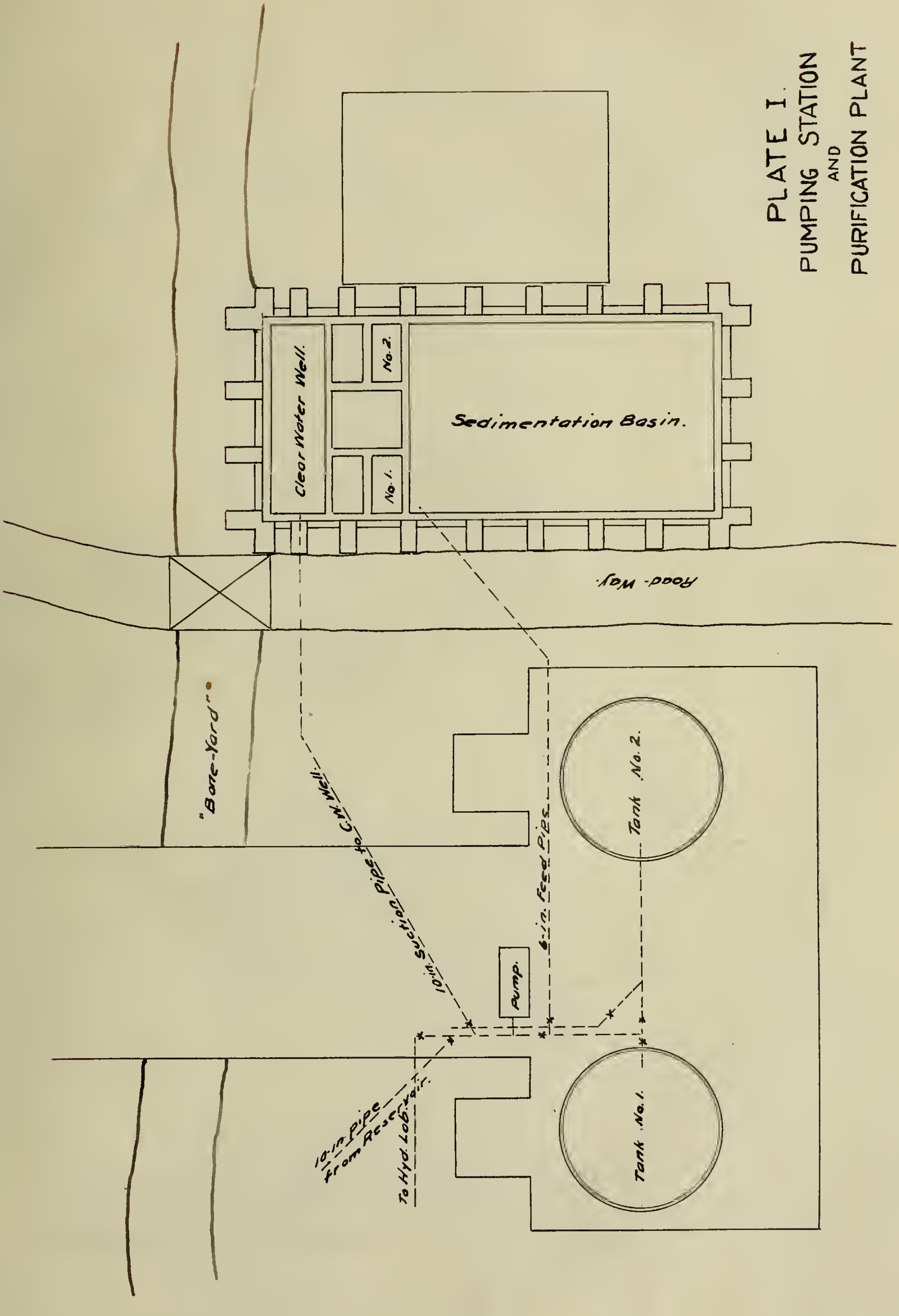


PLATE I.
PUMPING STATION
AND
PURIFICATION PLANT

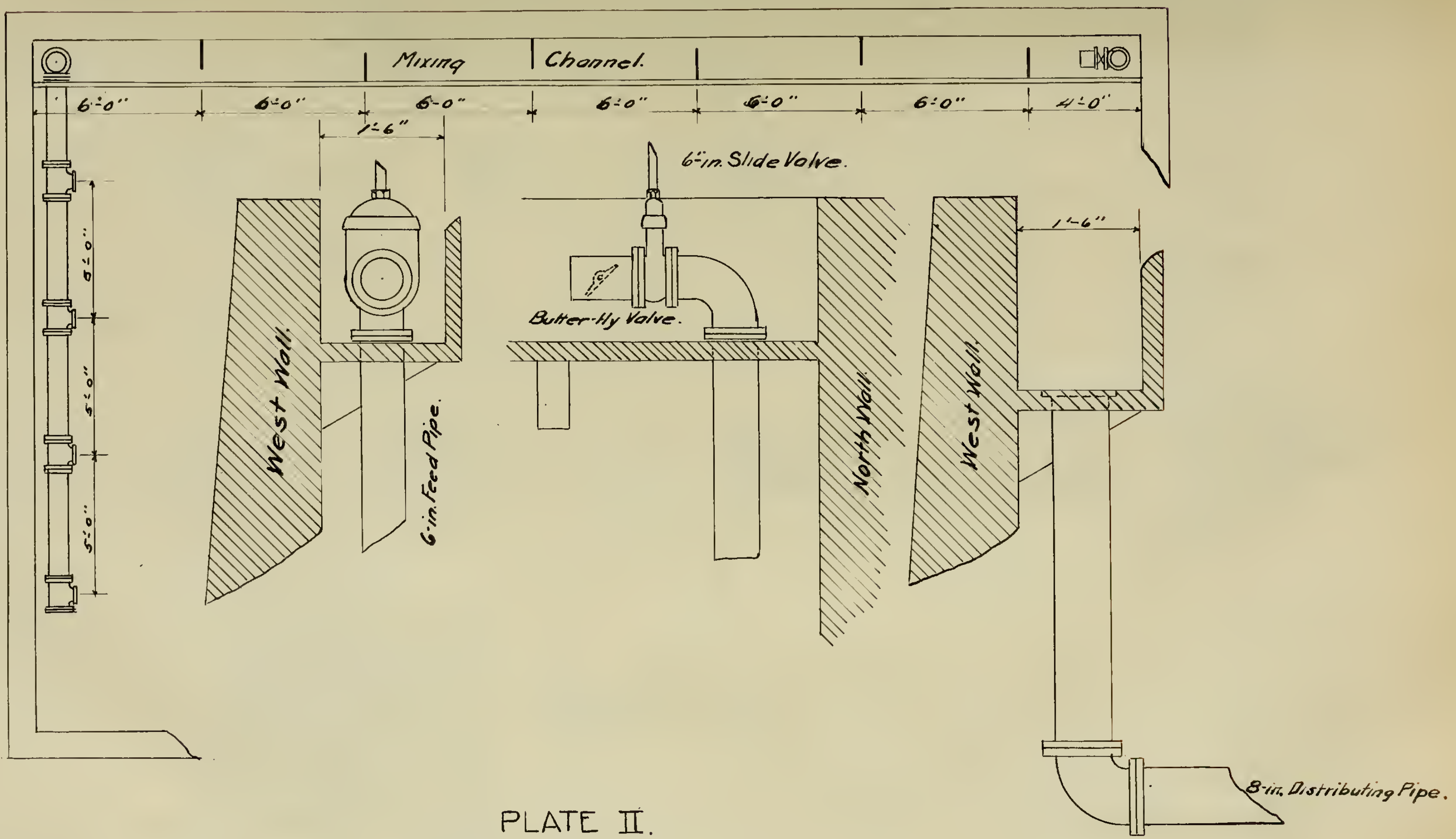


PLATE II.
SEDIMENTATION BASIN
DETAILS OF
INLET

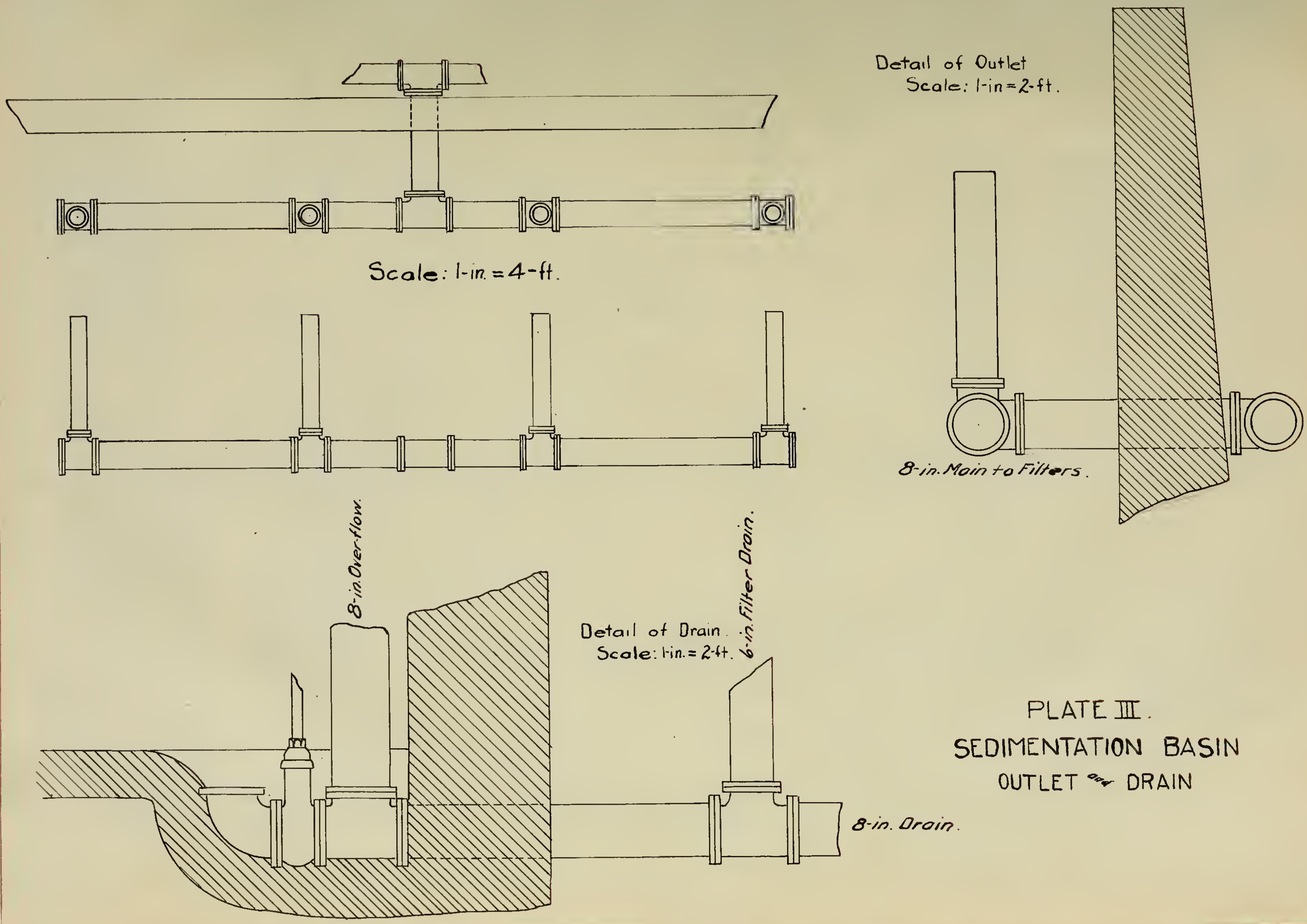


PLATE III.
SEDIMENTATION BASIN
OUTLET and DRAIN

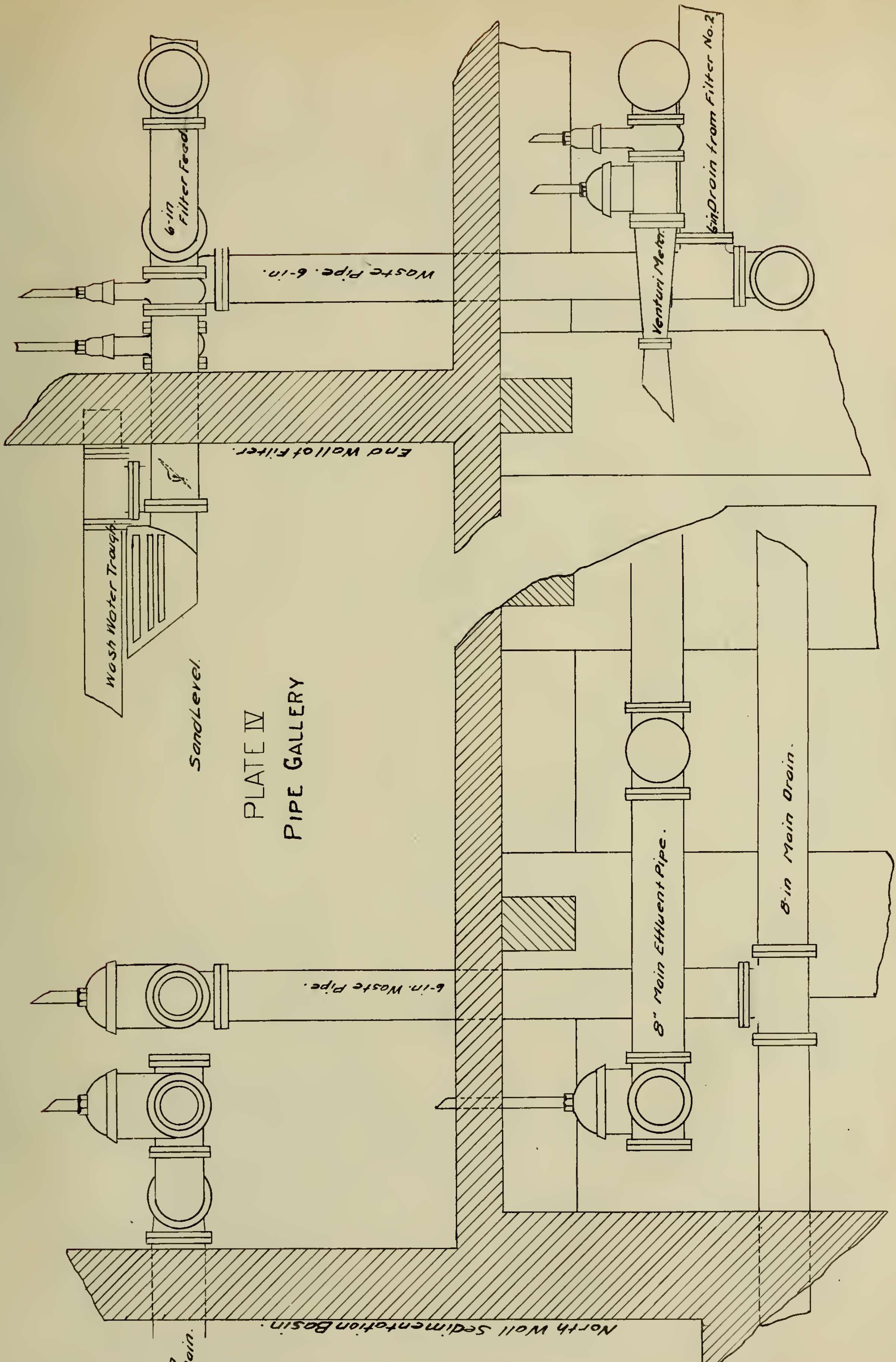
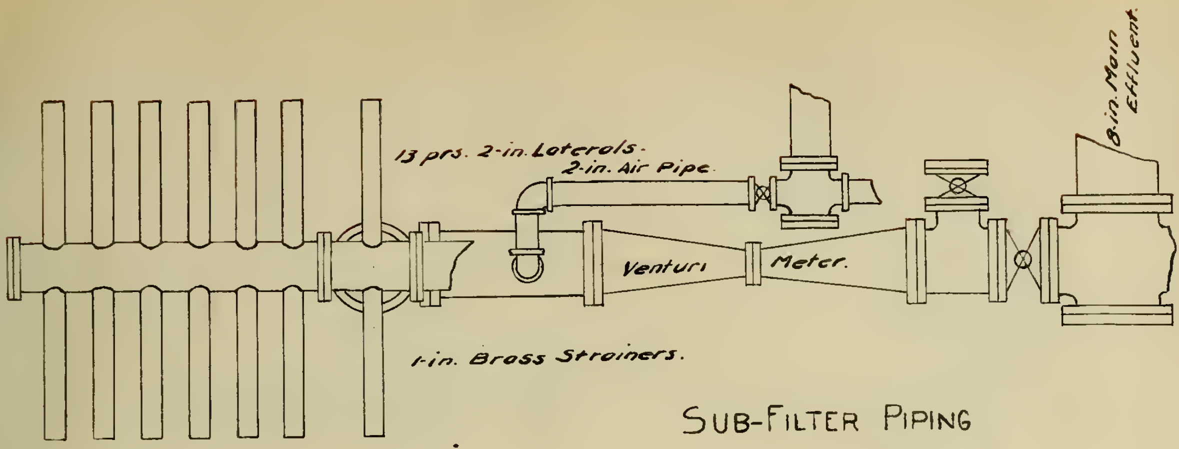
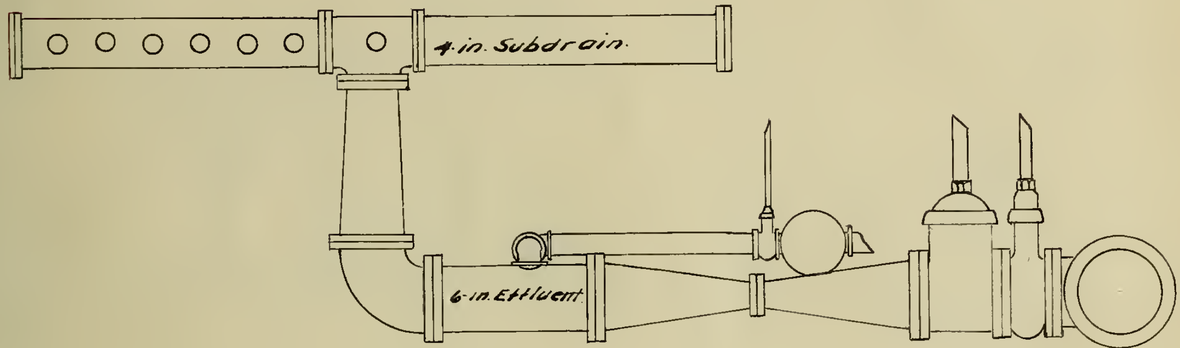


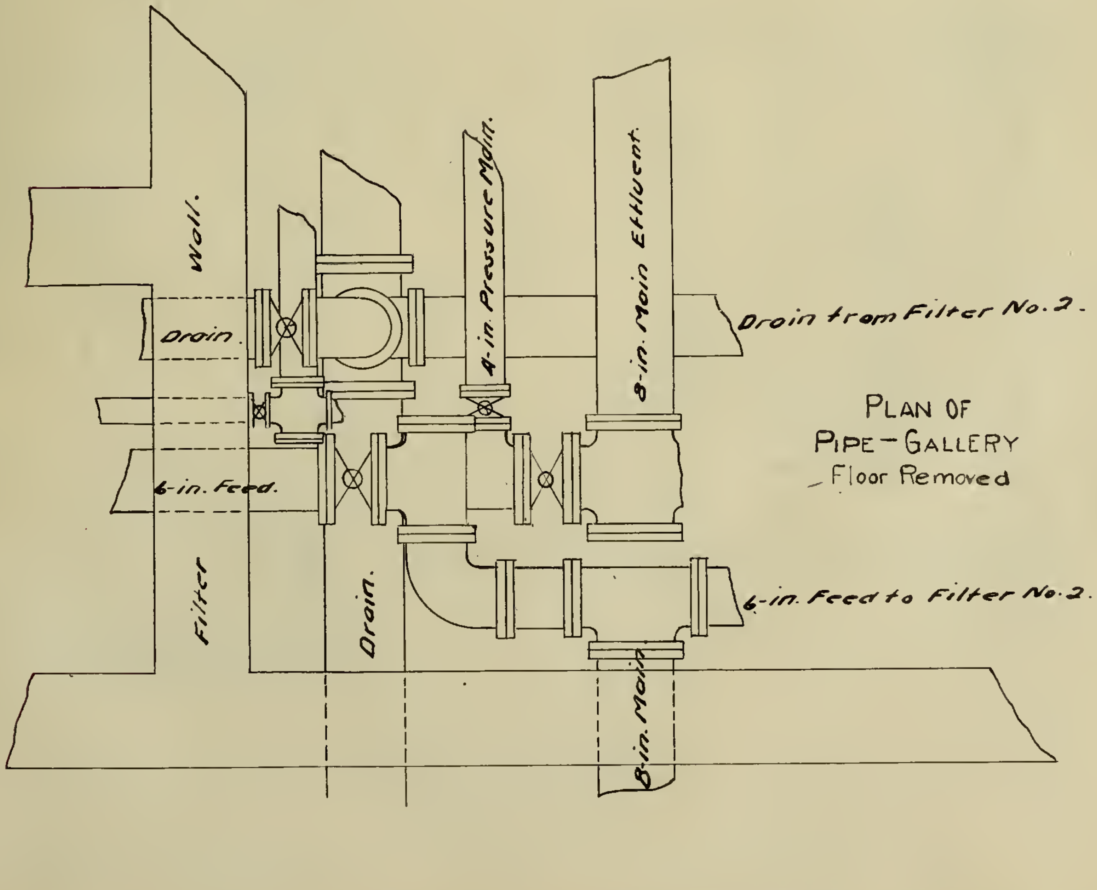
PLATE IV
PIPE GALLERY
6-in Filter Feed
Waste Pipe. 6-in.
End Wall of Filter
Wash Water Trough
Sand Level
Venturi Meter
6-in Drain from Filter No. 2
8" Main Effluent Pipe.
8-in Main Drain.
6-in. Waste Pipe.
North Wall Sedimentation Basin.
8-in Main.

PLATE V.



SUB-FILTER PIPING





PLAN OF
PIPE-GALLERY
Floor Removed

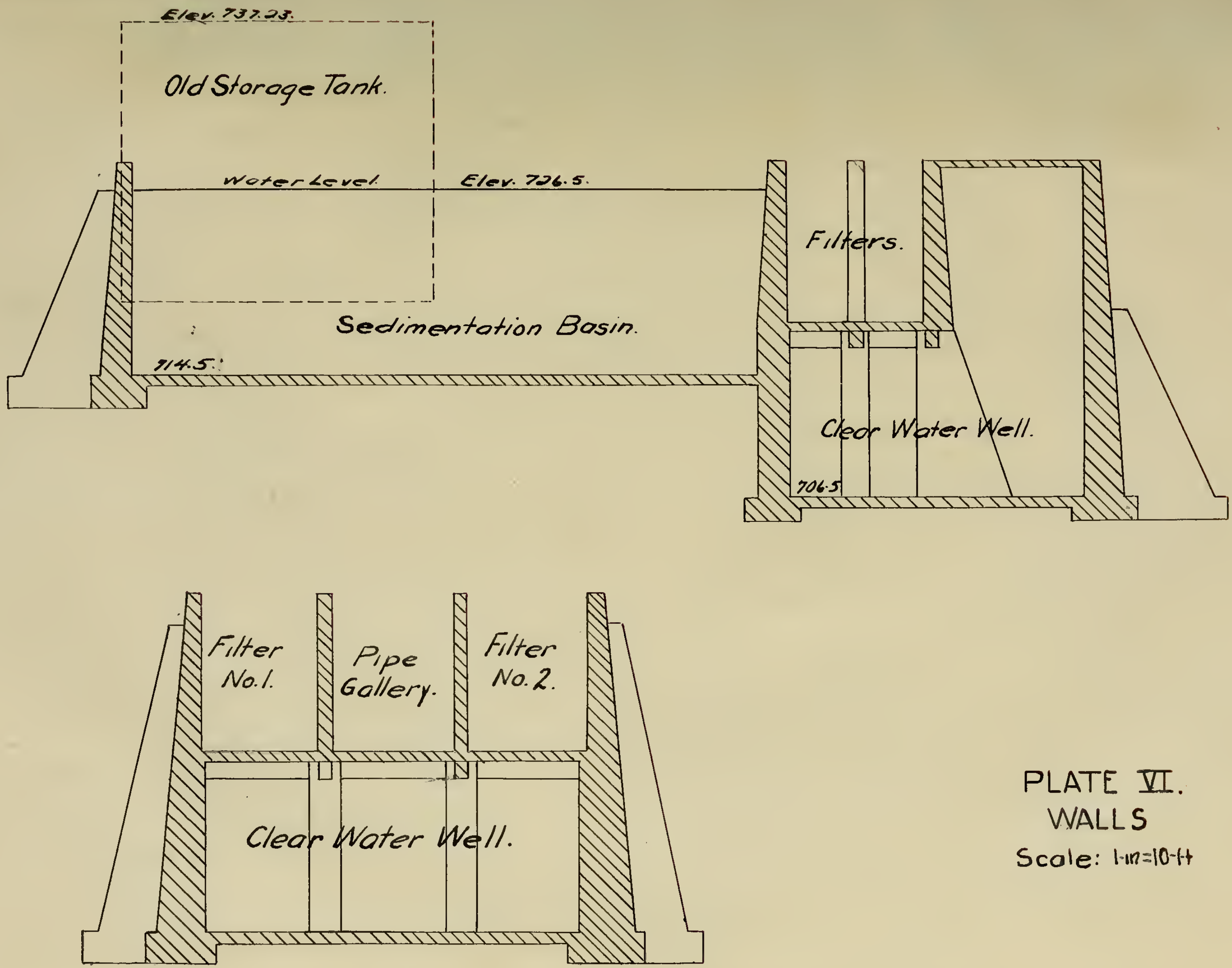


PLATE VI.
WALLS
Scale: 1 in = 10 ft